(12) EUROPEAN PATENT APPLICATION

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant:
Sony International (Europe) GmbH
50829 Köln-Ossendorf (DE)

(72) Inventors:
• Böhnke, Ralf,
c/o Sony International (Eur) GmbH
70736 Fellbach (DE)

• Dölle, Thomas,
c/o Sony International (Eur) GmbH
70736 Fellbach (DE)
• Konschak, Tino,
c/o Sony International (Eur) GmbH
70736 Fellbach (DE)

(74) Representative:
Rupp, Christian, Dipl.Phys. et al
Mitscherlich & Partner
Patent- und Rechtsanwälte
Sonnenstrasse 33
80331 München (DE)

(54) Soft decision method and apparatus for 8PSK demodulation

(57) The present invention provides for a method and a demodulator for demodulating a 8-PSK modulated signal. The down converted symbol is split (1) in its I and Q components which are supplied as a first and a second bit (Bit1,Bit0) as a soft input to a soft input decoder like a Viterbi decoder (8). Furthermore the I and Q components of the received symbol are mapped into the first quadrant of the I and Q coordinate plain by

means of absolute calculation units (2,3). The symbol mapped into the first quadrant is then rotated in the complex plain by 45 degree. The in-phase component of the phase-shifted mapped symbol is then output as a soft decision (likelihood) information to the soft input decoder (8).

FIG 2

EP 0 987 863 A1
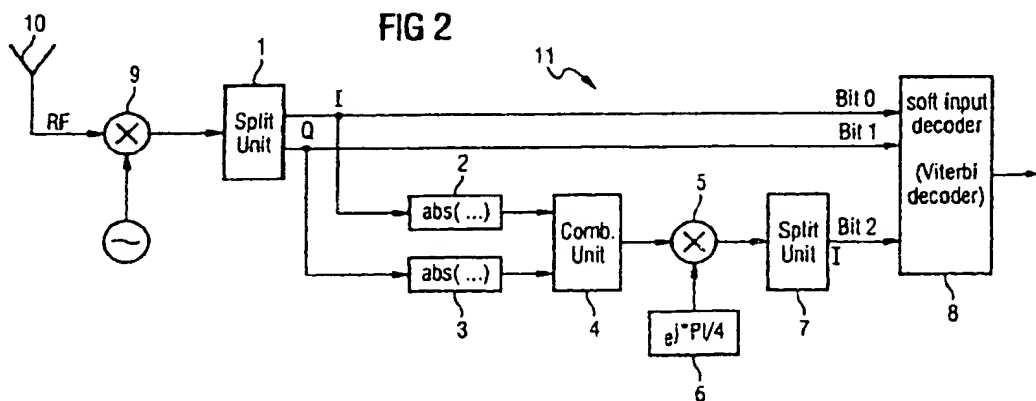
Description

[0001]   The present invention relates to a method for demodulating a 8 PSK modulated signal, a demodulator for demodulating a 8 PSK modulated signal as well as to a mobile communications device comprising such a demodulator.

[0002]   When demodulating a 4-PSK (QPSK) modulated signal it is known to generate soft information besides the hard decision information. As the inphase and quadrature phase component can be separated easily in the QPSK system (orthogonal signal space) it is quite simple to generate the soft information representing the likelihood of the received symbol. Fig. 3 shows the modulation point constellation scheme according to the QPSK scheme. As shown in fig. 4, split unit one separates the inphase component to generate a bit 0 and a Q-phase component to generate the bit one. Furthermore a third bit is issued representing the soft information, i.e. the likelihood of the received symbol.

[0003]   However, when demodulating a 8 PSK modulated signal, the soft information generation process as known from the QPSK modulation scheme can no longer be used as there is no longer any orthogonal signal space. Therefore according to the state of the art a typical 8 PSK demodulation process generates only hard decision information. To generate the hard decision information (e.g. + and -1) decision sectors (threshold comparison) is introduced. The hard decision of the received symbol represents the sector in which the received constellation point has been detected. According to the detected sector three bits B0, B1, B2 are generated according to the hard decision. According to this prior art no soft decision information enhancing the quality of the decoding process is generated.

[0004]   Compared to QPSK(4-PSK) where the I and Q (in-phase and quadrature)components can be separated completely (orthogonal space), the generation of soft information (confidence or likelihood information) in a 8-PSK receiver therefore is more complicated.

[0005]   From US-A-5757856 a differential encoder and decoder for a Trellis-encoded 8 PSK modulation is known. In fig. 1 of the document a 8 PSK type coded signal constellation is shown and explained.

[0006]   JT04-123553 discloses a monitor system for octal phase PSK demodulation.

[0007]   Therefore it is the object of the present invention to provide for a system generating additionally soft decision information when demodulating a 8-PSK modulated signal.

[0008]   This object is achieved by means of the features of the independent claims. The dependent claims develop further the centrality of the present invention.

[0009]   According to the present invention therefore a method for demodulating a 8-PSK modulating signal is provided. At first the I and Q components of the received symbol are detected. A first and a second soft

decision bit representing the detected I and Q components, respectively, are output. The distance from the received symbol to the closest axis of a coordinate system rotated by 45° relatively to the I and Q coordinate system is detected and a third bit representing the measure distance is output. The third bit therefore represents also a soft decision or likelihood information.

[0010]   The distance from the received symbol to the closest axis of a coordinate system rotated by 45° degrees relatively to the I and Q coordinate system can be measured by mapping the received symbol into the first quadrant of the I and Q coordinate system. Then the mapped constellation point is phase rotated by 45° and the I component of the phase rotated mapped constellation point is taken. The I component of the phase rotated mapped constellation point therefore represents the likelihood or soft decision information.

[0011]   The mapping of the received symbol is in the first quadrant of the I and Q coordinate system can be affected by taking the absolute value of the I and Q components of the received symbol.

[0012]   The three bits generated by a demodulation method according to the present invention, i.e. the three soft decision bits can be supplied to a Viterbi decoding step, wherein the third bit representing the method distance is used as a likelihood information in the Viterbi decoding step. The Viterbi decoding thereby stands as an example for convolutional decoding techniques, which are an example for general soft input decoding techniques.

[0013]   The third bit can be supplied as an input signal to a carrier phase tracking loop.

[0014]   The third bit can be supplied as an input signal to an automatic gain control.

[0015]   Regarding the 8 PSK constellation mapping scheme, a Gray constellation mapping can be used.

[0016]   According to the present invention furthermore a demodulator for demodulating a 8 PSK demodulated signal is provided. The demodulator comprises a split unit adapted for detecting the I and Q components (separating the I and Q components) of the received symbol, and outputting a first and a second bit representing the detected I and Q components. Furthermore a detector is provided adapted for detecting the distance from the received symbol to the closest axis of a coordinate system rotated by 45° relatively to the I and Q coordinate system and for outputting a third bit representing the measured distance.

[0017]   The detector for measuring the distance from the received symbol to the closest axis of the coordinate system rotated by 45° relatively to the I and Q coordinate system can comprise means for mapping the received symbol to the first quadrant of the I and Q coordinate system, means for phase rotating the mapped constellation point by 45°, and means taking the I component of the phase rotated mapped constellation point.

[0018]   The means for mapping the received symbol into the first quadrant of the I and Q coordinate system

can comprise means for taking the absolute value of the I and Q components of the received symbol.

[0019] Furthermore a Viterbi decoder can be provided, wherein the three bits representing the measure distance are used as a likelihood information in the Viterbi decoder.

[0020] A carrier phase tracking loop can be provided to be supplied to the third bit as an input signal.

[0021] An automatic gain control can be supplied with a third bit information signal as an input signal.

[0022] According to the present invention furthermore a mobile communications device is provided comprising a demodulator as set forth above.

[0023] In the following a preferred embodiment of the present invention will be explained with reference to the figures of the enclosed drawings such that further objects, features and advantages provided by the present invention will become clearer.

Fig. 1 shows a 8-PSK modulation point constellation scheme and two coordinate systems, i.e. the I-Q coordinate system as well as the second coordinate system build up from virtual axes and rotated by 45° relatively to the I-Q coordinate system,

fig. 2 shows a block diagram of an embodiment of the present invention, wherein the soft decision information (likelihood information) is input to a Viterbi decoder,

fig. 3 shows a known QPSK constellation scheme, and

fig. 4 shows a split unit for separating the I and Q component of a QPSK modulated symbol.

[0024] With reference to Fig. 1 the basic idea of the present invention will be explained. In fig. 1 the modulation point constellation scheme of a gray-coded 8-PSK modulation system is shown. Furthermore the I-Q coordinate system as well as a second coordinate system build up of orthogonal axes A1, A2 is shown. The second coordinate system build up from the axes A1, A2 is shifted by 45° relatively to the I-Q coordinate system. By providing a second coordinate system, with other words an orthogonal signal space also for 8-PSK modulation can be generated. For higher order modulation schemes, such as for example 16-PSK modulation, further coordinate systems and virtual axes can be introduced.

[0025] According to the present invention firstly the I and Q components of the received symbol are detected and respectively output as a first and a second bit. This information can be used as soft information or it can be decided in which decision sector the received symbol is positioned (hard decision) and only data representing the decided sector is generated and supplied to a decoder.

[0026] In another step the received symbols are projected on the axes of the second coordinate system build up from the axes A1, A2 and the distance from the received symbol to the closest axes A1, A2 of said coordinate system is measured. Said measured distance is then output as soft decision or likelihood information and can be used in a convolutional decoder, such as for example a Viterbi decoder.

[0027] With reference to fig. 2 an embodiment of the implementation of the present invention will be explained. Fig. 2 shows a demodulator 11 for the demodulation of a 8-PSK modulated signal according to the present invention. The 8-PSK modulated RF signal is received from an antenna 10 and then passed to a baseband down converter 9. The base band converted signal is then split in a split unit 1 in the inphase component and quadrature phase component. The split unit 1 therefore generates the inphase quadrature phase component of the incoming complex constellation. The inphase information and the quadrature phase information are respectively output as a bit 0 and a bit 1. These two bits 0 and bit 1 are input in a convolutional decoder such as Viterbi decoder 8.

[0028] Additionally according to the present invention the received complex symbol constellation is mapped in the first quadrant. Therefore an absolute calculation unit 2 is provided for the inphase component and an absolute value calculation unit 3 is provided for the quadrature phase component. The absolute calculation unit 2, 3 maps all incoming complex symbol constellations to the first quadrant in the complex plane. The implementation of the absolute calculation unit 2, 3 is therefore quite simple. If the incoming symbol value is ≥ 0, no change is required, and if the signal value is < 0, the sign of the symbol is inverted(flipping of the sign bit).

[0029] The output signals of the absolute calculation units 2, 3 are input to a combination unit 4. The combination unit 4 uses the two inputs from the absolute calculation unit 2, 3 to generate a complex constellation point in the complex IQ plain. The complex constellation point generated by the combination unit 4 is then rotated by 45° or PI/4 in the complex domain by means of a phase adding unit 6 providing a phase shift of 45° or PI/4 and a multiplier 5. In the implementation therefore one addition and two multiplications have to be effected (as later on only the I-part is used).

[0030] The phase rotated mapped symbol is then input to a second split unit 7. The second split unit 7 takes only the inphase value of the mapped phase shifted symbol to generate a soft information value. Therefore by passing only the inphase component of the received symbol to the output a third bit (bit 2) is generated and can be input to the Viterbi decoder as likelihood information.

[0031] The scheme as explained with reference to fig. 1 and 2 is both applicable to coherent 8-PSK modulation and differential 8-PSK modulation. The scheme is furthermore independent of the actual transmission

technology (single carrier, multicarrier, ...).

[0032] In the following a calculation example will be used to demonstrate the processing effected by the structure shown in figure 2:

The received constellation point is: = 0,72*exp(j*1.1*PI) = -0,685+j(-0.222) The split unit 1 generates the decisions: Bit0=-0.685 (inphase component), Bit1=-0.222 (quadrature component).

[0033] After the comb unit 4 the following complex constellation is present: 0.685+j(0.222) = 0.72*ep(j*0.1*PI).

[0034] After the (PI/4) rotation unit 5, 6 the signal is: 0.72*exp(j*0.35PI) = 0.327+j*(0.642)

[0035] After the second split unit 7 (taking the only I part) the decision is for B2 = 0.327 Therefore B2=0.327 is output as soft decision likelihood information bit in this calculation example.

[0036] In advanced transmission systems convolutional codes are used. Convolutional decoders (like Viterbi algorithm based decoders) show excellent performance if "softinformation" (likelihood) is available besides the symbol decision itself Likelihood information expresses the confidence of the decision and is taken into account in the maximum-likelihood decoding process. For Reed-Solomon or in general block codes the likelihood (confidence) information can be used as an indication for ensure and improve the decoding process.

[0037] Even if no coding is applied the availability of soft information can be used in the communication system to improve the performance (e.g. as input to a carrier phase tracking loop, input to AGC=automatic gain control).

[0038] With the structure according to the present invention soft-information during the demodulation process. The scheme is capable of generating soft-output values which take into account the strength of the received constellation point (power of the received symbol) and the position ("deviation" from the optimum point = middle of the sector).

[0039] The advantages and the character of the present invention can be summarized as follows:

- Maximum likelihood information is generated with 8-PSK constellations which improves overall system performances with a simple decoder structure.
- No complicated calculations are needed (like absolute phase calculation).
- The usage of Gray constellation mapping reduced the error events.
- The smaller confidence of "Bit3" (result of the transmitter constellation diagram) is already taken into account in the demodulator structure.
- The structure can be seen as a simple extension of 4-PSK (QPSK) modulation/demodulation schemes and therefore implementation of flexible (softinformation) QPSK/8PSK demodulators is simplified.

Claims

1. Method for demodulating a 8 PSK modulated signal, comprising the following steps:

   - detecting (1) the I and Q components of a received symbol,
   - outputting a first and a second bit comprising likelihood information and representing the detected I and Q components,
   - detecting (2, 3, 4, 5, 6, 7) the distance from the received symbol to the closest axis of a coordinate system rotated by 45 degrees relatively to the I and Q coordinate system, and
   - outputting a third bit representing the measured distance.

2. Method for demodulating according to claim 1, characterized in that the distance from the received symbol to the closest axis of a coordinate system rotated by 45 degrees relatively to the I and Q coordinate system is measured by

   - mapping (2, 3) the received symbol into the first quadrant of the I and Q coordinate system,
   - phase rotating (5, 6) the mapped constellation point by 45 degrees, and
   - taking (7) the I component of the phase rotated mapped constellation point.

3. Method for demodulating according to claim 2, characterized in that the mapping of the received symbol into the first quadrant of the I and Q coordinate system is effected by taking (2, 3) the absolute value of the I and Q components of the received symbol.

4. Method for demodulating according to anyone of the preceding claims, characterized by the step of supplying the three bits to a Viterbi decoding step (8), wherein the third bit representing the measured distance is used as a likelihood information in the Viterbi decoding step (8).

5. Method for demodulating according to anyone of the preceding claims, characterized by the step of supplying the third bit as an input signal to a carrier phase tracking loop.

6. Method for demodulating according to anyone of the preceding claims, characterized by the step of supplying the third bit as an input signal to an automatic gain control.

7. Method for demodulating according to anyone of the preceding claims,
   characterized in that
   a Gray constellation mapping is used.

8. Demodulator for demodulating a 8 PSK modulated signal,
   comprising :

   - a split unit (1) adapted for detecting the I and Q components of a received symbol and outputting a first and a second bit representing the detected I and Q components,
   - a detector (2, 3, 4, 5, 6, 7) adapted for detecting the distance from the received symbol to the closest axis of a coordinate system rotated by 45 degrees relatively to the I and Q coordinate system and for outputting a third bit representing the measured distance.

9. Demodulator according to claim 8,
   characterized in that
   the detector for measuring the distance from the received symbol to the closest axis of a coordinate system rotated by 45 degrees relatively to the I and Q coordinate system comprises:

   - means (2, 3) for mapping the received symbol into the first quadrant of the I and Q coordinate system,
   - means (5, 6) for phase rotating the mapped constellation point by 45 degrees, and
   - means (7) for taking the I component of the phase rotated mapped constellation point.

10. Demodulator according to claim 9,
    characterized in that
    the means for mapping the received symbol into the first quadrant of the I and Q coordinate system comprises means (2, 3) for taking the absolute value of the I and Q components of the received symbol.

11. Demodulator according to anyone of claims 8 to 10,
    characterized by
    a soft input decoder, like a Viterbi decoder (8), wherein the three bits representing the measured distance are used as a likelihood information in said soft input decoder (8).

12. Demodulator according to anyone of claims 8 to 11,
    characterized by
    a carrier phase tracking loop supplied with the third bit as an input signal.

13. Demodulator according to anyone of claims 8 to 12,
    characterized by
    an automatic gain control supplied with the third bit

as an input signal.

14. Demodulator according to anyone of claims 8 to 13,
    characterized in that
    a Gray constellation mapping is used.

15. Mobile communications device,
    characterized in that
    it comprises a demodulator (11) according to anyone of claims 8 to 14.
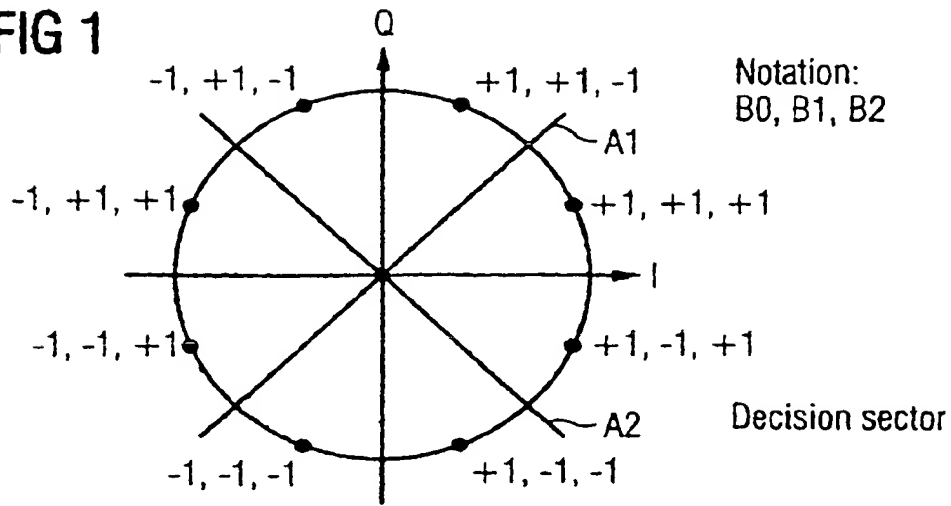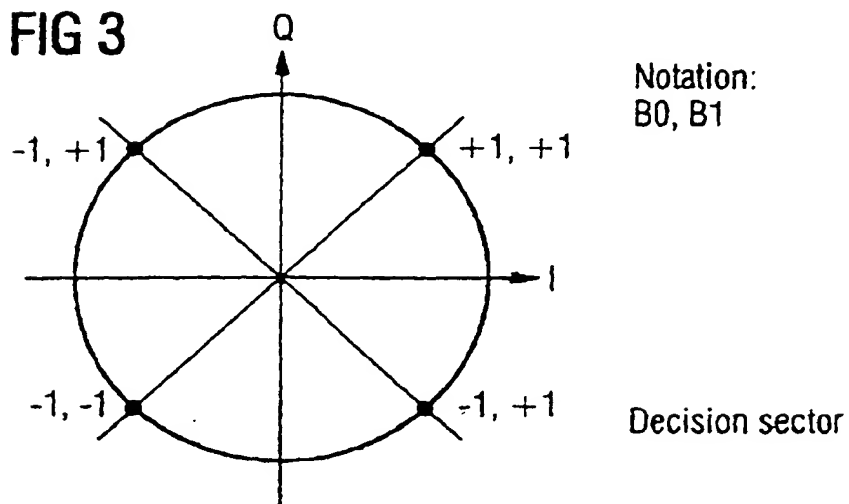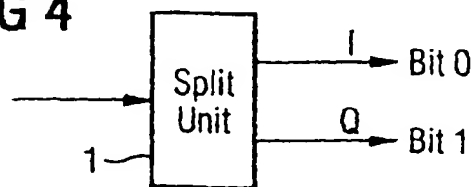
FIG 1

Q

-1, +1, -1   +1, +1, -1

A1

-1, +1, +1   +1, +1, +1

I

-1, -1, +1   +1, -1, +1

A2

-1, -1, -1   +1, -1, -1

Notation:
B0, B1, B2

Decision sector

FIG 3

Q

-1, +1   +1, +1

I

-1, -1   -1, +1

Notation:
B0, B1

Decision sector

FIG 4

Split Unit

1

I → Bit 0

Q → Bit 1

6

FIG 2
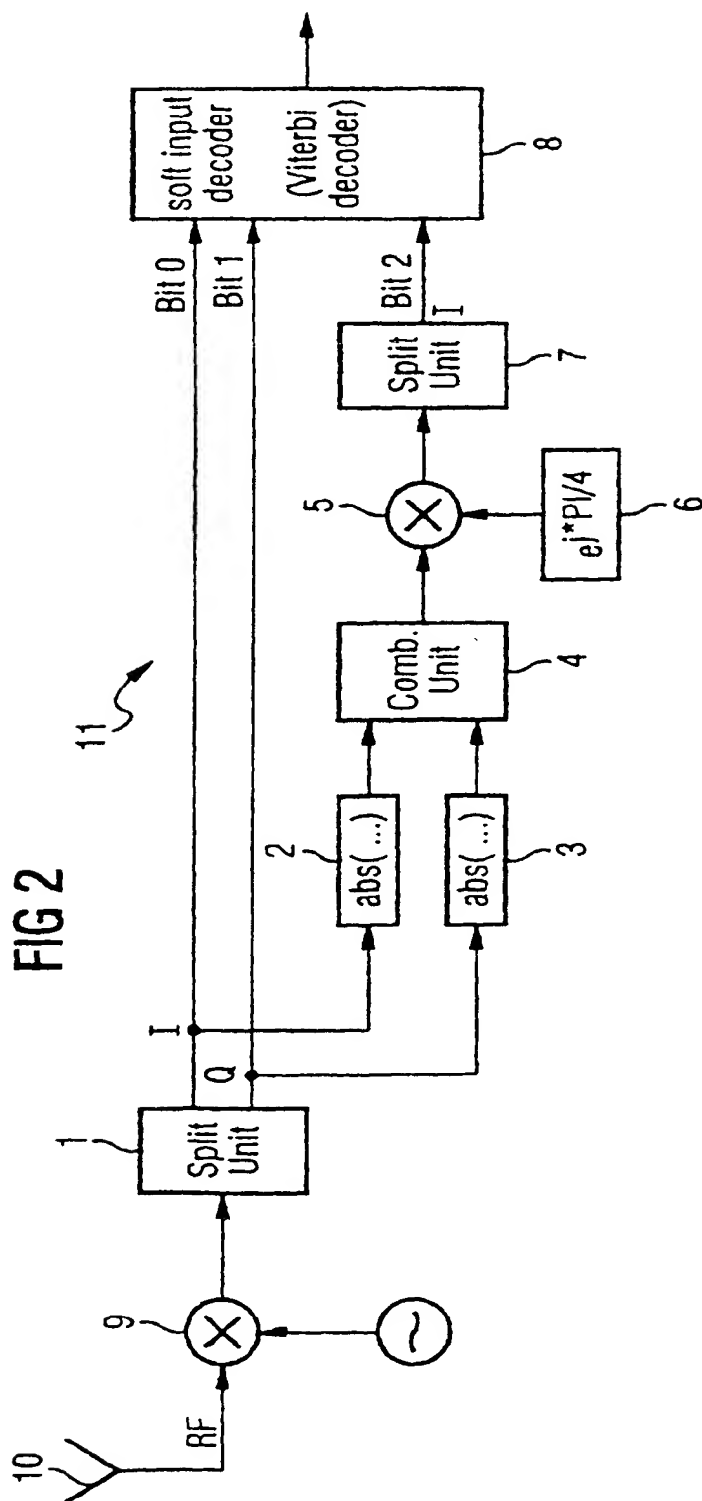
	European Patent Office	EUROPEAN SEARCH REPORT		Application Number EP 98 11 7678

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 519 891 A (HUGHES AIRCRAFT CO) 23 December 1992 * column 1, line 21 - line 37 * * figure 3 *	1,8	H04L27/233 H04L27/227
A	US 4 250 458 A (RICHMOND ROBERT L ET AL) 10 February 1981 * column 1, line 56 - column 2, line 40 * * figure 1 *	1,8	
A	BUDA FABIEN ; FANG JUING ; SEHIER PHILIPPE: "Soft decoding of BCH codes applied to multilevel modulation codes for Rayleigh fading channels" IEEE MILITARY COMMUNICATIONS CONFERENCE MILCOM, vol. 1, 2 - 5 November 1997, pages 32-36, XP002093340 Monterey, CA, USA * section 3.2.1 * * figure 4 *	1,8	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H04L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 February 1999	De Riccardis, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03 82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 98 11 7678

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

19-02-1999

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0519891	A	23-12-1992	US 5311545 A	10-05-1994
US 4250458	A	10-02-1981	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82